Energy Policy 116 (2018) 433–443

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

Meeting conditional targets in nationally determined contributions of developing countries: Renewable energy targets and required investment of GGGI member and partner countries

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ARTICLE INFO

Keywords:
Climate change
NDCs
Renewable energy investment
Developing countries
GGGI

ABSTRACT

Under the Paris Agreement, countries submitted nationally determined contributions (NDCs) including their GHG emission reduction targets and mitigation measures. Around 175 Parties have mentioned in their NDCs to reduce energy sector emissions by increasing the share of renewable energy in the energy mix. Dissemination of renewable energy requires substantial investment and low and middle-income developing countries tend to present conditional targets assuming external support, therefore essential to estimate how much funding developing countries require and explore how they attract international investment to meet their renewable energy targets. This study examines contributions to carbon mitigation and necessary investment for expansion of renewable energy in Global Green Growth Institute (GGGI) member countries by analyzing their NDCs and national energy plans. It is estimated that the 27 GGGI member and partner countries analyzed in this study would conditionally reduce at least 5058 $MtCO_{2eq}$ of GHG by 2030 and increase the cumulative renewable energy generation capacity up to around 356,184 MW by 2030. To accomplish these pledges, an investment of at least US$258 billion will be required by 2030: US$98–260 billion for solar photovoltaics (PV); US$76–139 billion for wind energy; US$57–330 billion for hydropower; US$10–23 billion for bioenergy; and US$16–45 billion for geothermal.

1. Introduction

After long discussion on the post-Kyoto framework for climate change, the Paris Agreement was adopted by 195 countries at the 21st session of the Conference of the Parties (COP 21) to the United Nations Framework Convention on Climate Change (UNFCCC) in December 2015, and came into force on November 4, 2016, with the ratification of 74 Parties accounting 59% of the total global greenhouse gas (GHG) emissions (UNFCCC, 2016a). In contrast with Kyoto protocol, which imposed binding GHG emission reduction targets on only 37 industrialized countries under the principle of common but differentiated responsibilities (CBDR), the Paris Agreement creates a regime that includes emissions reduction targets for all signatories. For this purpose, it requires each country to present intended nationally determined contribution (INDC) which contain post-2020 national action plans that the country intends to take to tackle the climate change (UNFCCC, 2016b). INDC of a country converts to binding nationally determined contribution (NDC) when the country ratifies the Paris Agreement. As of January 2018, 166 INDCs of 194 Parties including 28 EU member states and 139 NDCs of 167 Parties have been submitted to the UNFCCC secretariat.

Although NDCs cover both mitigation and adaptation, mitigation targets and the measures to achieve them are a central part in NDCs (Rogelj et al., 2016), due to their central role to achieving the objective of the Paris Agreement, to limit the global average temperature increase to "well below 2^0C" while "pursuing efforts to limit the increase to 1.5 °C" (UNFCCC, 2016b). Two patterns are conspicuous among the mitigation plans described in the communicated NDCs. First, among various measures to reduce GHG emissions, one of the most common measures is promotion of renewable energy. Out of 194 Parties submitting their INDCs, 193 Parties (99.5%) have pledged to reduce the GHG emissions in energy sector including transportation and buildings.[1] In particular, 176 Parties (91%) have mentioned that they would increase the share of renewable energy as a way to reduce energy sector

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[1] Besides energy sector, land-use, land-use change and forestry (LULUCF, 80%), waste management (77%), agriculture (74%) and industrial process (62%) are the main sectors that the Parties have pledged their mitigation contribution.

https://doi.org/10.1016/j.enpol.2018.02.017
Received 6 November 2017; Received in revised form 9 February 2018; Accepted 10 February 2018
Available online 06 March 2018
0301-4215/

emissions. Second, low and middle-income developing countries tend to set mitigation targets that were either entirely conditional (targets requiring international support, in the form of climate finance, technology transfer or capacity building) or a were a mix of conditional and unconditional targets. To reduce GHG emissions is, in general, costly and to expand renewable energy requires substantial investment due to the high upfront costs (Betzold, 2016). Thus, it is difficult for many developing countries to implement effective mitigation policies in the renewable energy sector with only their domestic resources, and this situation is reflected in the setting of targets conditional on external assistance.

While many developing countries are willing and ready to meet the more ambitious conditional targets, many will only be able to if they can get international financial and technological assistance. In addition, the principles of historical responsibility and CBDR enshrined in the UNFCCC obligate developed countries to help support climate change action by developing countries. While NDCs contain a variety of conditional targets, the Paris Agreement itself does not outline the support needed by developing countries or the support pledged by developed countries. In this regard, it is essential to estimate how much funding developing countries require to reach their conditional renewable energy targets and explore how they can attract international investment.

As part of such an effort, this study examines overall GHG emissions mitigation and necessary investment for renewable energy expansion in Global Green Growth Institute (GGGI) member countries by analyzing their NDCs and national energy plans. GGGI is a young international organization that works to support and promote a sustainable and inclusive model of economic growth, defined as green growth, in its member countries. Since GGGI particularly focuses on rooting the concept of green growth in developing countries and emerging economies, most of its member countries are developing countries with conditional or combined targets in their NDCs. Additionally, GGGI as part of its green growth-related efforts, supports its member countries across a wide range of climate-related activities, including in renewable energy expansion and access to climate finance. Therefore, GGGI member countries and the role of GGGI in supporting developing country access to domestic and international sources of climate finance present interesting case studies that are potentially scalable to other developing countries.

This paper is organized as follows: Section 2 explores previous studies analyzing INDCs and NDCs; Section 3 describes the methodology used in this study, including data collection, assumptions for estimation of GHG emission reductions and investment in renewable energy; Section 4 outlines NDCs of GGGI member countries (and INDCs where they have not yet been converted to NDCs) and presents their GHG emissions reduction targets; Section 5 compiles renewable energy targets and estimates the investment needed to meet those targets, with a focus on GGGI member countries' conditional targets; Section 6 discusses how those countries can secure the funding and ways GGGI supports countries to access renewable energy finance; and Section 7 concludes with key findings and implications.

2. Trends of research on NDCs

Many international organizations and researchers have reviewed and analyzed INDCs and NDCs since the initial submission of INDCs before COP 21. The most frequent type of studies is evaluating the aggregate effect of NDCs at the global scale (Admiraal et al., 2015; Boyd et al., 2015; den Elzen et al., 2016; Rogelj et al., 2016; UNEP, 2016; UNFCCC, 2015, 2016c; Vandyck et al., 2016). In other words, they estimate overall GHG emissions if the NDCs are fully implemented and assess whether those contributions are sufficient to hold the average global temperature rise well below 2^0C. The initial work of the UNFCCC Secretariat (2015) and the updated report (UNFCCC, 2016c) respectively review 119 INDCs communicated by 147 Parties including 28 EU member states by October 2015, and 161 INDCs communicated by 189 Parties by April 2016. Admiraal et al. (2015) assessed the mitigation components of the 74 INDCs, and Boyd et al. (2015) compared global emissions under various scenarios with 126 INDCs. Also, den Elzen et al. (2016) and Rogelj et al. (2016) assessed the mitigation potential of 79 INDCs and 160 INDCs respectively. Their common conclusion is that the GHG emission levels resulting from implementation of the current INDCs/NDCs are much lower than business-as-usual (BAU) scenarios, but higher than the levels required to keep the global average temperature increase below 2^0C. They suggest, therefore, that enhanced long-term actions be undertaken to address climate change.

Some studies narrow the scope of analysis and focus on a group of countries (den Elzen et al., 2016; Höhne et al., 2017; Liu et al., 2017; Kuramochi et al., 2017; UNEP, 2016; van Soest et al., 2017). UNEP (2016) and den Elzen et al. (2016) evaluate the contributions of G20 countries to global GHG emissions reduction. According to den Elzen et al. (2016), G20 countries, in particular, Brazil, China, EU and the U.S., play an important role in global GHG mitigation efforts, but conclude that the global emission levels will be still higher in 2030 than they were in 2010. UNEP (2016) also states that while G20 members generally present ambitious mitigation measures, some countries have the potential to achieve greater reductions than their pledged INDC targets. Van Soest et al. (2017) compared GHG emission trajectories of 11 major economies including Brazil, Canada, China, EU, India, Japan, Mexico, Russia, South Korea, Turkey and the U.S., with the integrated assessment models (IAMs), cost-optimal 450 ppm CO_2eq mitigation scenarios, and their NDCs. They found that some countries, such as Brazil, Canada, EU, Mexico (conditional NDC), South Korea and the U.S. have ambitious targets, but underscore that the NDCs of the 11 countries are insufficient to hold the increase in the global average temperature below 2^0C, in general. Höhne et al. (2017) compared the pledges of China, EU, and the US, and concluded the EU made the most ambitious contribution in terms of GHG emission reductions. Liu et al. (2017) simulated GHG emissions of the EU, US, China and India under the three scenarios (BAU, INDC and API) and showed the differences in GHG emissions in 2020 and 2030 of each country depending on the scenarios. They concluded China and India would achieve the biggest GHG reduction under API scenario while the EU and the US would do under the INDC scenario.

Regarding costs of implementing NDCs, relatively few studies have been undertaken in comparison to evaluation of NDC pledges. Hof et al. (2017) calculated the annual abatement costs of achieving the GHG emission reduction targets in the NDCs using the IMAGE integrated assessment model. They estimated the global abatement costs of achieving unconditional NDCs at US$135 billion by 2030, and US $40–55 billion would be needed for full implementation of the additional conditional targets. However, they emphasized these figures are dependent on a range of socio-economic assumptions. Rai (2015) estimated US$53.8 billion would be required annually between 2020 and 2030 to implement mitigation measures in the NDCs of the 48 Least Developed Countries (LDCs). Muñoz Cabré and Sokona (2016) focused on the energy sector and estimated the investment for unconditional renewable energy contributions included in the NDCs of African countries. Out of the 54 African countries, 28 countries pledged unconditional renewable energy targets in their NDCs. They estimated the cumulative renewable energy target of the 28 countries would increase renewable energy generation capacity to 102 GW or more, and require an investment of at least US$241 billion to achieve the target.

Even though NDCs are a relatively new concept, many articles have been published. However, the analysis of NDCs tends to concentrate on the estimation of aggregate global mitigation effect and overall mitigation costs. In addition, research on the NDCs focused on low and middle-income developing countries emitting relatively lower level of GHGs is less common. First, most studies concentrating on limited sets of countries rather than global analysis have focused on developed countries and large economies such as those of the G20. Second, studies analyzing low and middle-income developing countries have their own

Table 1
GGGI member and partner countries.

Member only (11 countries)	Operations only (Partner) (8 countries)	Member & operation (17 countries)
Australia, Costa Rica, Denmark, *Guyana*, Hungary, Republic of Korea, Norway, *Papua New Guinea*, *Paraguay*, *Qatar*, United Kingdom (U.K.)	China, *Colombia*, *India*, *Morocco*, *Mozambique*, *Myanmar*, *Nepal*, *Uganda*	*Cambodia*, *Ethiopia*, *Fiji*, *Indonesia*, *Jordan*, *Kiribati*, *Lao PDR*, *Mexico*, *Mongolia*, *Peru*, *Philippines*, *Rwanda*, *Senegal*, *Thailand*, United Arab Emirates, *Vanuatu*, *Vietnam*

limitations. Amponin and Evans (2016) compared NDCs of developing member countries (DMCs) of the Asian Development Bank (ADB), but this work primarily focused on the description of the content contained in NDCs of individual DMCs. Kuramochi et al. (2017) tracked GHG emissions and mitigation policies of various developing countries such as Argentina, Colombia, Democratic Republic of the Congo, Ethiopia, Indonesia, Kazakhstan, Mexico, the Philippines, South Africa, and Thailand, and assessed if they could achieve the targets in NDCs by 2030 with current policies. Even though it provides a valuable analysis, it does not discuss why those countries cannot meet the targets and how they can achieve the targets.

There is no doubt that research related to the impact of NDCs of developed countries and large economies as major emitters are important, since both have high potential and capacity for addressing climate change. However, the fact that climate change is a common global challenge means every country must contribute to mitigate GHG emissions. Thus, every developing country must also meet its targets, and the consideration of how their conditional targets can be achieved is timely.

3. Data and methodology

3.1. The scope of analysis

In this study, we estimate the required investment to increase the share of renewable energy in developing countries and meet the conditional renewable energy-sector mitigation targets in GGGI member and partner countries. GGGI member and partner countries in this study include both countries that are members of GGGI (referred to hereafter as member countries), in some of which GGGI also conducts operations, and those in which GGGI only has operations (referred to hereafter as partner countries). GGGI has 28 members and operates in an additional 8 partner countries, which are presented in Table 1. After assessing the GHG mitigation targets of those 36 countries, the analysis of the renewable energy targets concentrates on the 27 countries (italics in Table 1) with conditional or combined targets in their NDCs. The other nine countries pledged only unconditional commitment and are excluded from further study as they do not require international financial assistance to achieve their targets. Narrowing the scope of analysis to only countries pledging conditional or combined targets will be more appropriate to the purpose of this study, the estimation of international funding to be gathered for the contribution of developing countries to the global GHG emissions reduction.

3.2. Data

For the objective of this study, three kinds of data are required: GHG emissions reduction targets; renewable energy targets; and the costs of renewable energy technologies. Various sources were used to construct the dataset. First, GHG emissions reduction targets have been identified from submitted NDCs and INDCs. For 31 countries, NDCs were compiled, and for the 5 countries that have not yet submitted their first NDCs—Colombia, Mozambique, Myanmar, Philippines, and Senegal—INDCs were collected. Where countries did not state clear reduction targets in their NDCs, data provided by GGGI's country teams and from the Australian-German Climate and Energy College were used.

Three methods were used to collect data on countries' renewable energy targets. First, the targets were extracted from NDCs and INDCs for countries that specified quantitative targets explicitly in their NDCs and INDCs. If such data was not included in the NDCs/INDCs, other official sources such as national energy plans and reports from other organizations specializing in renewable energy, such as the International Renewable Energy Agency (IRENA) and the Renewable Energy Policy Network for the 21st Century (REN21) were reviewed. Finally, GGGI's country teams consulted with local experts to fill in remaining data gaps. Data on the cost of renewable energy was obtained from the recent regional Levelized Cost of Electricity (LCOE)[2] by REN21 (2017).

3.3. Methodology

NDCs are not standardized in terms of content, methodology to estimate GHG emissions, the type of reduction target, and so on. Thus, the following approaches are applied to the estimate the GHG emission reductions of GGGI countries. First, figures stated by in NDCs were used without revision where they include absolute emission reductions targets related to a specific target year. This is the case for 11 countries including Australia, Cambodia, Costa Rica, Ethiopia, Guyana, Kiribati, Lao PDR, Mozambique, Nepal, UAE, and Vanuatu. Second, in the case of countries providing reduction targets in percentage terms, the reductions are computed using BAU emissions in target year or emissions in the baseline year. 19 countries, including Colombia, Denmark, Fiji, Hungary, Indonesia, Jordan, Mexico, Mongolia, Morocco, Norway, Paraguay, Peru, Philippines, Republic of Korea, Senegal, Thailand, Uganda, the U.K., and Vietnam fall into this category. For Denmark, Hungary and the U.K., the total target of EU was used because EU member states submitted one NDC as a group. Third, for China and India which provided the targets related to a reduction in carbon intensity, this study used the estimated reduction projected by Liu et al. (2017). They reported the difference in the future emissions for the BAU and INDC scenario of China and India projected with emission model simulation based on final energy consumption and intensity by sector and ratio of fossil fuel and clean energy in final energy consumption. Fourth, in the case of Papua New Guinea, it is assumed that it would reduce the same amount of GHGs as BAU emissions in 2030 since it presented carbon neutrality as the target. Finally, it is assumed that Myanmar, Qatar, and Rwanda have conditional targets that are comparable to the minimum targets set by GGGI countries located in the same regions since they do not include overall emission reduction targets in their NDCs or INDCs. For instance, this study assumes Myanmar has set the same target as Thailand and Vietnam—25% reduction compared to BAU emissions in 2030—and whose reduction targets are the lowest among GGGI countries in Southeast Asia.

In addition, both cases of unconditional targets and conditional targets are estimated to show the difference in potential GHG emissions reduction between two targets. For countries whose NDCs only include unconditional targets, this study assumes that their emission reductions would be the same in both unconditional and conditional scenarios. For

[2] LCOE is an average total cost of building, operating, and maintaining a power generating plants divided by a total energy output over its lifetime.

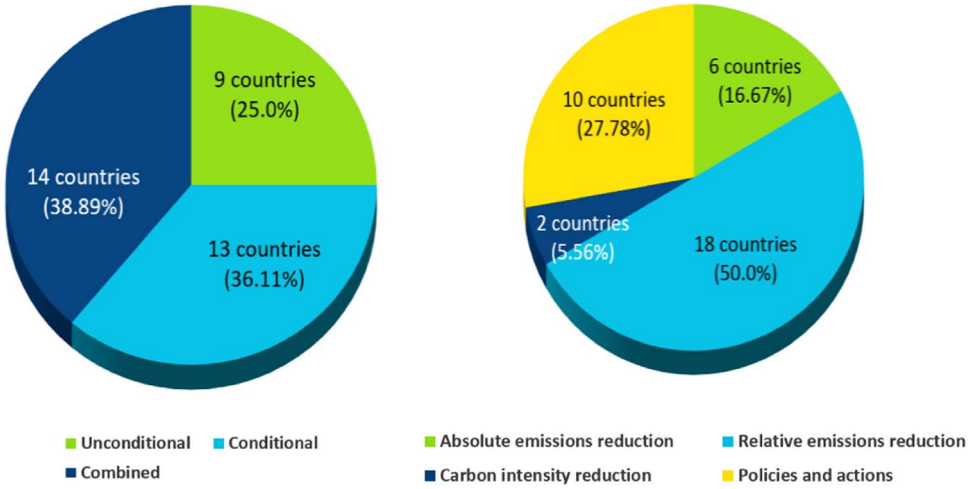

Fig. 1. Conditionality and target types of GGGI member countries.

countries whose NDCs include only conditional targets, this study assumes that emissions follow the current emission levels for the unconditional scenario, that is, emission reductions are zero.

For the renewable energy targets, some assumptions and approximations are inevitable due to ambiguities and gaps in official national data. The first challenge is ensuring that the targets are expressed in terms of capacity in megawatts (MW). While renewable energy targets within NDCs are often expressed in MW (renewable energy capacity target), not all countries list renewable energy targets as capacity terms. Some indicate targets only in terms of investment or energy facilities, such as the expected number of power plants in 2030. Since the objective of this study is to quantify the renewable energy targets to determine investment needs, this study uses renewable energy capacity targets and all other types of renewable energy targets were converted into MW. Second, for countries that did not present technology-specific targets, the total renewable target was distributed to each technology in accordance with the most recent share of that technology in the countries renewable energy mix. This is the case for Cambodia, Mozambique, Paraguay, Qatar, and Uganda. For example, Qatar set the target that 20% of electricity be generated from renewable energy by 2030, but the specific targets for technology including solar PV, wind, and bioenergy were not stated in official documents. The total renewable energy target in 2030 is converted to capacity terms using projections on electricity consumption in 2030 by IRENA (2016). The total renewable energy target is further disaggregated by technology by dividing the total capacity target by the share of each technology in the renewable energy mix in 2016 (in the case of Qatar, solar PV 13.6% and bioenergy 86.4%). Consequently, this study assumes that 49 MW of solar PV (1800 MW × 20% × 13.6%) and 311 MW of bioenergy (1800 MW × 20% × 86.4%) by 2030 are the technology disaggregated renewable energy targets of Qatar.

Several assumptions are also necessary for the estimation of required investment. First, it is assumed that international funding supports only newly installed facilities, while existing facilities are operated under national budgets. Since most renewable energy targets are cumulative targets installed by target year, capacity in 2016 was subtracted from the targets to identify additional capacity. Second, for additional installation, the annual linear increase of capacity is assumed. For example, Senegal pledged to install 160 MW of solar PV by 2030. It is assumed that Senegal can build additional 106 MW with international financial assistance since 54 MW of solar PV generators were already operated in 2016, and it would increase the capacity gradually from 2021 to 2030, starting from 10.6 MW in 2021 and approaching 106 MW in 2030 with the annual increase by 10.6 MW. Third, in the case of countries whose target years are before 2030 (generally 2025), it is assumed that facilities installed after target year would be covered by the national budget, so capacity supported by international assistance would be maintained the same from the target year to 2030. Under these assumptions, potential investment needs from 2021 to 2030, implementation period of NDCs, are estimated using regional LCOE and capacity factor provided by REN21 (2017) as follows:

$$\textit{Required Investment} = 24 \times 365 \times C_{ij} L_{ij} \sum_{k=1}^{10} kX_{ij}$$

where C = capacity factor, L = LCOE,

X = (renewable energy target – installed capacity)/10,
i = technology, j = country

Although much endeavor has been made to get the most plausible estimation, this analysis is still imperfect due to the quality of available data. Insufficiency of data and information poses one of the biggest challenges to conducting studies in developing countries. While this study referred to numerous data sources, specific information disaggregating targets by technology were not found for some countries, and a number of assumptions and approximation were made in order to make up the missing data.

4. GHG emissions reduction pledged by GGGI member countries

4.1. Review of GGGI member countries' NDCs

All 36 GGGI member and partner countries submitted INDCs, and 31 countries—excluding Colombia, Mozambique, Myanmar, Philippines, and Senegal—submitted their first NDCs. In most of countries, the first NDCs were simply converted from their initial INDCs, however Indonesia and Morocco submitted updated versions of their INDCs as their first NDCs. While Indonesia added more details on the BAU scenarios with the same mitigation targets, Morocco increased their mitigation target from a 13% unconditional reduction with an additional 19% conditional reduction, to a 17% unconditional reduction with an additional 25% conditional reduction by 2030 compared to the BAU scenario. (Fig. 1)

Table 2 provides an overview of the mitigation targets and measures presented in the INDCs and NDCs of GGGI member and partner countries. Almost all countries—except Guyana, Nepal, and the United Arab Emirates (UAE)—set their targets to achieve by 2030. Guyana's NDC covers the period up to 2025, while Nepal and the UAE did not clearly state target year. Since GGGI member and partner countries are predominately developing countries, more than two-thirds include

Table 2
Mitigation plans of GGGI member countries.

Country	Conditionality	Mitigation type	Baseline	Mitigation target	Estimated reduction (MtCO2eq)	
					Unconditional	Total
Australia	Unconditional	Absolute	2005	26–28% reduction	158.86–171.08[a]	158.86–171.08[a]
Cambodia	Conditional	Relative	BAU (2030)	27% reduction	0[a]	3.13[a]
China	Unconditional	Carbon intensity	2005	• 60–65% intensity reduction • CO_2 emission peak around 2030 • Share of non-fossil fuels: 20%	1039.00[b]	1039.00[b]
Colombia	Combined	Relative	BAU (2030)	30% reduction (unconditional 20% + conditional 10%)	67.00[a]	100.50[a]
Costa Rica	Unconditional	Absolute	2012	Maximum emissions: 9.37 $MtCO_{2eq}$	3.08[a]	3.08[a]
Denmark, Hungary United Kingdom (EU)	Unconditional	Absolute	1990	at least 40% reduction	2250.40[a,*]	2250.40[a,*]
Ethiopia	Conditional	Relative	BAU (2030)	64% reduction	0[a]	255.00[a]
Fiji	Combined	Relative	BAU (2030)	30% reduction (unconditional 10% + conditional 20%)	0.25[a]	0.75[a]
Guyana	Combined	Policies & actions	BAU (2025)	• Unconditional: expansion of renewable energy supply • • Conditional: 100% renewable power supply & reforms in the timber and mining industries	0[a]	51.00 – 52.20[a]
India	Conditional	Carbon intensity	2005	• 33–35% intensity reduction • Share of non-fossil fuels: 40%	0[b]	− 25.00[b]
Indonesia	Combined	Relative	BAU (2030)	41% reduction (unconditional 29% + conditional 12%)	832.01[a]	1176.29[a]
Jordan	Combined	Relative	BAU (2030)	14% reduction (unconditional 1.5% + conditional 12.5%)	0.77[a]	7.14[a]
Kiribati	Combined	Relative	BAU (2030)	61.8% reduction (unconditional 12.8% + conditional: 49%)	0.10[a]	0.49[a]
Lao PDR	Conditional	Policies & actions	n/a	To increase forest cover and the share of renewable energy to meet 30% of energy consumption, etc.	0[a]	1528.00–1537.00[a]
Mexico	Combined	Relative	BAU (2030)	40% reduction (unconditional 25% + conditional 15%)	277.50[a]	444.00[a]
Mongolia	Conditional	Policies & actions	BAU (2030)	To increase renewable electricity capacity and reduce electricity transmission losses, etc.	0[a]	7.17[a]
Morocco	Combined	Relative	BAU (2030)	42% reduction (unconditional 17% + conditional 25%)	269.42[a]	665.62[a]
Mozambique	Conditional	Policies & actions	n/a	To implement national policies' and program's actions	0[a]	76.5[a]
Myanmar	Conditional	Policies & actions	n/a	To undertake mitigation actions in line with sustainable development needs	0[c]	27.75[c]
Nepal	Conditional	Policies & actions	n/a	To contribute to the global efforts of reducing GHG emissions	0[d]	5.5[d]
Norway	Unconditional	Absolute	1990	at least 40% reduction	20.80[a]	20.80[a]
Papua New Guinea	Conditional	Relative	BAU (2030)	carbon neutrality	0[a]	18.00[a]
Paraguay	Combined	Relative	BAU (2030)	20% reduction (unconditional 10% + conditional 10%)	41.60[a]	83.20[a]
Peru	Combined	Relative	BAU (2030)	30% reduction (unconditional 10% + conditional 20%)	29.83[a]	89.49[a]
Philippines	Conditional	Relative	BAU (2030)	70% reduction	0[a]	158.20[a]
Qatar	Conditional	Policies & actions	n/a	Economic diversification	0[c]	16.80[c]
The Republic of Korea	Unconditional	Relative	BAU (2030)	37% reduction	314.72[a]	314.72[a]
Rwanda	Conditional	Policies & actions	BAU (2030)	To achieve energy security and a low-carbon energy supply that support the development of green industry	0[c]	4.20[c]
Senegal	Combined	Relative	BAU (2030)	21% reduction (unconditional 5% + conditional 16%)	3.05[a]	12.81[a]
Thailand	Combined	Relative	BAU (2030)	25% reduction (unconditional 20% + conditional 5%)	111.00[a]	137.50[a]
Uganda	Combined	Policies & actions	BAU (2030)	To undertake a number of policies and measures to support low-carbon development	0[a]	17.01[a]
The United Arab Emirates	Unconditional	Policies & actions	n/a	To limit emissions and improve resilience through economic diversification	43.30[d]	43.30[d]
Vanuatu	Conditional	Relative	BAU (2030)	• 100% reduction for electricity • 30% reduction for whole energy sector	0[a]	0.07[a]
Vietnam	Combined	Relative	BAU (2030)	25% reduction (unconditional 8% + conditional 17%)	62.99	196.85

[a] : calculated based on the figures stated in NDCs.
[b] : estimated by Liu et al. (2017).
[c] : assumed the same as the lowest targets among GGGI countries in the same region since no relevant information exists.
[d] : estimated by GGGI country team /.
* : total target of 28 EU member states.

Table 3
Estimated GHG emissions reduction of GGGI member and partner countries by 2030 (GGGI Analysis).

Category	Unconditional reduction ($MtCO_{2eq}$)	Total reduction: unconditional & conditional ($MtCO_{2eq}$)
All countries	5525.68–5537.90	8888.12–8910.54
Countries pledging unconditional targets only	3830.16–3842.38	3830.16–3842.38
Countries pledging conditional targets only	–	2075.32–2084.32
Countries pledging combined targets	1695.51	2982.64–2983.84
Countries pledging conditional and combined targets	1695.51	5057.96–5068.16

conditional targets in their NDCs. Out of 36 countries, 13 countries committed to conditional targets only and 14 countries committed to combined targets including both unconditional and conditional pledges. Seven countries including Australia, Costa Rica, Denmark, Hungary, Norway, Republic of Korea and the U.K., which are mostly GGGI donor countries, committed to unconditional targets. China and the UAE did not specify whether their targets are conditional or unconditional, but owing to their economic growth and development level, it is reasonable to assume their targets are unconditional.

The targets contained in the NDCs were provided in various forms. Six countries set absolute emission reduction targets specifying maximum net emissions in the target year or percentage reduction compared to specific historical baselines allowing translation into fixed numerical values. 18 countries presented relative emission reduction targets, which set the percent of GHG emissions the country will reduce when compared to the BAU emission scenario in the target year. Unlike absolute targets, relative targets change depending on the countries' BAU scenarios. Two countries—China and India—pledged to lower their carbon intensity[3] by 60–65% and 33–35% respectively compared to 2005 levels, and increase the share of non-fossil fuels in the energy supply up to 20% and 40% respectively. China also pledged to achieve the peak of CO_2 emissions around 2030. The other 10 countries enumerated their policies and actions to reduce the GHG emissions without specifying overall numeric targets (Table 2; Fig. 1).

GGGI member and partner countries listed mitigation activities across various sectors: energy including transportation and buildings (100%), LULUCF (89%), waste management (81%), agriculture (72%) and industrial process (70%). Particularly, 32 countries (89%) showed their willingness to promote renewable energy and 25 countries (70%) provided specific programs for afforestation and sustainable land management. While majority of countries regarded the increase in the share of renewable energy as a main activity for GHG emissions reduction, some Southeast Asian countries including Indonesia, Cambodia and Myanmar put the higher priority on afforestation or expected bigger mitigation effects from the LULUCF sector.

4.2. Estimated GHG emissions reduction

The last two columns of Table 2 show the estimated GHG emission reductions of each GGGI member and partner country. The "unconditional" column presents estimated GHG emission reductions when only unconditional targets are met, and the "total" column presents the estimated GHG reduction when conditional targets are achieved in addition to unconditional targets. When full achievement of unconditional NDC targets is assumed, China will reduce GHG emissions the most as an individual country, and its reduction should be approximately 1039 $MtCO_{2eq}$. Denmark, Hungary, and the U.K. will reduce approximately 2250 $MtCO_{2eq}$ of GHG emissions together with other EU member states. For conditional targets, Lao PDR and Indonesia pledged ambitious targets, with estimated emissions reductions of 1537 $MtCO_{2eq}$, and 1176 $MtCO_{2eq}$ respectively.

[3] Carbon intensity usually indicates how many grams of carbon are emitted for one unit of GDP of a country.

The overall commitment of GGGI member and partner countries to GHG emission reduction ranges from 5525.68 to 8910.54 $MtCO_{2eq}$. They will reduce GHG emissions by approximately 5526 to 5538 $MtCO2_{eq}$ regardless of external assistance, and this amount can increase to approximately 8888 to 8911 $MtCO_{2eq}$ with international assistance to meet the conditional targets of developing countries in this sample. The 27 countries presenting conditional targets and combined targets pledged an additional 3362 to 3373 $MtCO_{2eq}$ of GHG emission reductions dependent on the availability of external financial resources. (Table 3) This amount is about 60% of total unconditional targets of GGGI member and partner countries, and is likely higher as the overall target of EU is used to estimate the unconditional target of Denmark, Hungary, and the U.K. Thus, the conditional targets of developing countries are not negligible in the global mitigation effort.

5. Renewable energy targets and required investments to meet conditional mitigation targets of GGGI member and partner countries

Renewable energy power generation is still costly relative to fossil fuel power generation, despite the declining price trends of renewable energy technologies. Thus, low and middle-income developing countries often depend on international financial assistance to increase the share of renewable energy. In this section, the renewable energy targets of the 27 GGGI member countries presenting conditional and combined targets in their NDCs are compiled, and the required investments to meet the targets are estimated.

5.1. Renewable energy targets

Table 4 shows the renewable energy targets of 27 GGGI member and partner countries presenting conditional and combined targets in their NDCs. Since NDCs usually include only generic targets about the renewable energy, this information has been complimented by detailed information from various sources including the national energy plans of individual countries. The sources are also included in Table 4. Most countries defined their renewable energy targets in terms of electricity, such as the percentage of total power generation, because renewable energy sources are mainly used for electricity generation (Timilsina and Shah, 2016). While the target year for GHGs mitigation in NDCs is often 2030, the target year for renewable energy varies from country to country.

The aggregate target of the 27 countries in this sample is an increase in the total renewable energy capacity up to approximately 356,184 MW. The technology expected to account for the largest share is solar PV (132,064 MW, 37%). Hydropower and onshore wind energy come in second and third at 105,708 MW (30%) and 93,347 MW (26%) respectively. Bioenergy (13,922 MW, 4%) and geothermal (11,143 MW, 3%) are estimated to have very low shares compared to solar PV, hydropower and wind energy. (Fig. 2)

5.2. Estimated costs

Table 5 presents the LCOE and capacity factors used in the estimation of required investment, and Table 6 shows the estimated total

Table 4
Renewable energy targets of 27 GGGI member countries presenting conditional and combined targets.

Country	Target type	Total target	Target capacity (MW)					Sources
			Solar PV	Wind	Hydro	Bio	Geothermal	
Cambodia	Electricity	25% by 2035 100% by 2050	22 [a] (by 2035)	0.45 [a] (by 2035)	1,682 [a] (by 2035)	36 [a] (by 2035)	-	Cambodia Ministry of Mines and Energy (2016); REN21 (2017)
Colombia	Electricity	6.5% by 2020 100% by 2050	239.2 (by 2030)	896 (by 2030)	-	248 (by 2030)	375 (by 2030)	IRENA (2015a); Colombia Ministry of Mines and Energy (2015); REN21 (2017)
Ethiopia	Electricity	100% by 2050	300 (by 2020)	1,224 (by 2020)	13,800 (by 2020)	257 (by 2020)	577 (by 2020)	REN21 (2017); Climate Scope 2016
Fiji	Final energy / Electricity	(F) 23% by 2030 (E) 100% by 2030	127 (by 2030)	-	84 (by 2030)	105 (by 2030)	-	Fiji Department of Energy (2013); GGGI country team; REN21 (2017)
Guyana	Final energy / Electricity	(F) 20% by 2025 (E) 100% by 2030	2.65 (by 2020)	20.375 (by 2020)	-	-	-	Guyana Energy Agency (2014); REN21 (2017)
India	Electricity	40% by 2030	100,000 (by 2022)	60,000 (by 2022)	10,000 (by 2022)	-	-	IRENA (2015b); NDC
Indonesia	Primary energy / Electricity	(P) 23% by 2025 (E) 31% by 2025	252.3 [a] (by 2026)	20.5 [a] (by 2026)	1,650 (by 2026)	5,427.2 [a] (by 2026)	6,300 (by 2026)	Climate Scope 2016; REN21 (2017)
Jordan	Primary energy / Electricity	(P) 11% by 2025	300 (by 2020)	1,200 (by 2020)	-	-	-	Government of Jordan (2007); REN21 (2017)
Kiribati	Electricity	3% by 2020 100% by 2050	4 [a] (by 2020)	-	-	-	-	REN21 (2017)
Lao PDR	Final energy	30% by 2025	33 (by 2025)	73 (by 2025)	400 (by 2025)	109 (by 2025)	-	ADB (2015); NDC
Mexico	Electricity	35% by 2024 50% by 2050	1,958 (by 2026)	12,032 (by 2026)	5,611 (by 2026)	767 (by 2026)	-	Mexico Secretaría de Energía (2012); REN (2017)
Mongolia	Primary energy / Electricity	(P) 20–25% by 2030 (E) 30% by 2030 100% by 2050	145 (by 2030)	354 (by 2030)	675 (by 2030)	-	-	NDC; REN21 (2017)
Morocco	Electricity	52% by 2030 100% by 2050	4,560 (by 2030)	4,200 (by 2030)	1,330 (by 2030)	-	-	Germanwatch (2016); NDC
Mozambique	Electricity	No quantitative term	-	1,100 (by 2025)	125 (by 2025)	-	-	NDC
Myanmar	Electricity	15–20% by 2020	3,202 (by 2030)	446 (by 2030)	198 (by 2030)	150 (by 2030)	-	IEA/IRENA Joint Policies and Measures Database; Myanmar National Energy Management Committee (2015);
Nepal	Primary energy / Electricity	(P) 10% by 2030 (E) 20% by 2020 100% by 2050	2,100 (by 2030)	-	12,050 (by 2030)	220 (by 2030)	-	NDC; REN21 (2017)
Papua New Guinea	Electricity	100% by 2030	8 (by 2020)	13 (by 2020)	580 (by 2020)	24 (by 2020)	112 (by 2020)	IRENA (2013); NDC
Paraguay	Electricity	60% increase from 2014 to 2030	-	-	14,096 [a] (by 2030)	62.4 [a] (by 2030)	-	REN21 (2017)
Peru	Electricity	60% by 2025	146 (by 2021)	232 (by 2021)	391 (by 2021)	-	-	Peru Ministry of Energy and Mines (2014); REN21 (2017)
Philippines	Electricity	40% by 2020 100% by 2050	285 (by 2030)	2,378 (by 2030)	8,724.1 (by 2030)	315.7 (by 2030)	3,461 (by 2030)	REN21 (2017); Tamang (2013)
Qatar	Electricity	2% by 2020 20% by 2030	48.95 [a] (by 2030)	-	-	311 [a] (by 2030)	-	IRENA (2016); REN21 (2017)
Rwanda	Electricity	60% by 2030 100% by 2050	17 (by 2030)	-	337 (by 2030)	-	310 (by 2025)	AfDB (2013); REN21 (2017)
Senegal	Electricity	20% by 2017 100% by 2050	160 (by 2030)	150 (by 2030)	144 (by 2030)	-	-	NDC; REN21 (2017)
Thailand	Final energy / Electricity	(F) 30% by 2036 (E) 20% by 2036	6,000 (by 2035)	3,002 (by 2030)	3,282 (by 2030)	5,570 (by 2030)	-	ADB (2015); REN21 (2017)
Uganda	Electricity	61% by 2017 3,200 MW by 2030	134.3 [a] (by 2030)	-	2,745.8 [a] (by 2030)	319.9 [a] (by 2030)	-	REN21 (2017)
Vanuatu	Electricity	65% by 2020 100% by 2030	20 (by 2025)	5.5 (by 2025)	3.4 (by 2020)		8 (by 2030)	Government of Vanuatu (2013); REN21 (2017)
Vietnam	Primary energy / Electricity	(P) 8% by 2025 11% by 2050 (E) 10.7% by 2030	12,000 (by 2030)	6,000 (by 2030)	27,800 (by 2030)	-	-	NDC; Thuc (N.D)
Total			132,064	93,347	105,708	13,922	11,143	

[a] Estimated based on the recent ratio of each technology.

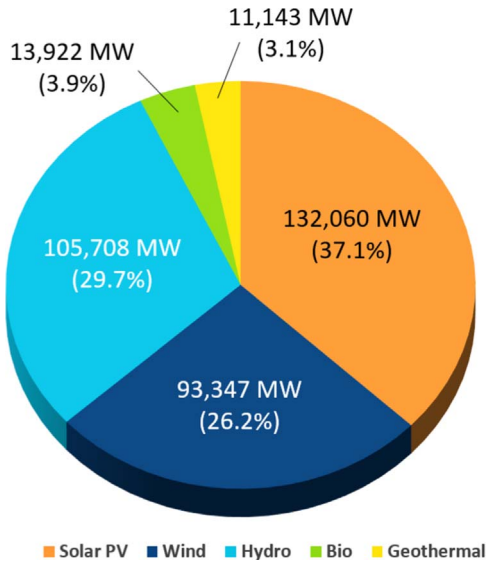

Fig. 2. Renewable energy targets of 27 GGGI member countries.

required investment to meet the combined and conditional renewable energy targets of the 27 GGGI member and partner countries.

The required investment was calculated using two scenarios: minimum LCOE scenario and maximum LCOE scenario.[4] From 2021–2030, US$11–32 billion will be required annually for the 27 countries in the sample using the minimum LCOE scenario, and US $33–108 billion will be needed annually using the maximum LCOE scenario (Fig. 3). The total estimated investment required to achieve the combined and conditional renewable energy targets by 2030 ranges US $258–797 billion, the top five countries in terms of investment required are: India (US$140–292 billion); Mexico (US$29–65 billion); Indonesia (US$18–53 billion); Ethiopia (US$15–92 billion); and Morocco (US $11–24 billion). The total estimated investment required, US$258–797 billion, represents 4–13% of the combined 2016 GDP of the 27 GGGI member and partner countries. In terms of annual GDP, Ethiopia (2–13%), Mongolia (1–3%), Morocco (1–2%), Mozambique (2–5%), Nepal (3–7%) and Paraguay (1–8%) require investment to reach combined and combined and conditional renewable energy targets greater than 1% of their national GDP.(Fig. 4)

Broken down by specific technologies, US$98–260 billion for solar PV, US$76–139 billion for wind energy, US$57–330 billion for hydropower, US$10–23 billion for bioenergy, and US$16–45 billion for geothermal are required to meet the combined and conditional renewable energy targets by 2030. Again, these required investments were estimated based on regional LCOE and capacity factor as of year 2016 provided by REN21 (2017). Of course, the estimated amounts can change depending on development of technology and discount rates. However, the change in price and capacity factor resulting from technology development and country-specific discount rates are much likely to increase uncertainty, and consequently, make more difficult to prepare for the future funding. In this sense, the latest data on cost and capacity factor was used for 2021–2030 without discount rates in order to avoid underestimation.

6. Discussion: Enabling to meet the conditional targets

Developing countries put a high priority on renewable energy in terms of not only GHG emission reductions but also from a sustainable development perspective, including energy security and rural electrification. Empirical results from the analysis on 23 countries including the Canada, Denmark, Indonesia, Japan, Kenya, Mexico, Norway, the U.S., and the U.K. show that increase in renewable energy consumption contributes to decrease in carbon emissions and increase in non-renewable energy consumption is correlated with the level of emissions (Dogan and Seker, 2016). In addition, Solar home systems and off-grid wind and small-hydro generation contribute to rural electrification, improving energy access in developing countries (Owusu and Asumadu-Sarkodie, 2016). Promoting renewable energy directly supports three of the UN Sustainable Development Goals (SDGs): No. 7 on affordable and clean energy; No. 11 on sustainable cities and communities; and No. 13 on climate action. Moreover, renewable energy reduces vulnerability to price fluctuations associated with imported fossil fuels and improves energy security.

However, the high upfront cost of renewable energy technologies makes it infeasible for developing countries to achieve renewable energy targets using only domestic sources of finance. The ideal should be growth of renewable energy market and increase in private sector investment, but the market is still not mature enough to attract private investment. Even developed countries still give subsidies to renewable energy sector. Especially, for developing countries, donor funding, historically, has been a necessary condition for implementation and sustainability of renewable energy projects (Betzold, 2016; Dornan and Shah, 2016). Muñoz Cabré and Sokona (2016) found it would be difficult for African countries to maintain investment levels equivalent to 2.5–3% of national GDP over more than 10 years. In fact, most of developing countries emphasized in their NDCs that they would not be able to achieve their targets without external assistance. In this sense, one of the main factors determining whether 27 GGGI member and partner countries will meet their conditional targets is access to international funding for renewable energy projects.

International climate financing has increased after the conclusion of Paris Agreement. The Green Climate Fund (GCF) was established in 2010 to mobilize finance to support the mitigation and adaptation activities of developing countries, many international organizations, including development banks, have committed to expanding the provision of climate finance, and considerable bilateral and multilateral assistance funds are available for renewable energy development (Dornan and Shah, 2016). Moreover, opportunities for private investment in renewable energy grew in the 2000s due to the concerns about oil prices and climate change, as well as the rapid growth of green bonds globally (REN21, 2017). In fact, climate finance flows recorded US$437 billion in 2015 and US$383 billion in 2016 owing to private investment in renewable energy sector in the China, Japan and the U.S., and the average amount of two years are 12% higher than during 2013 and 2014 (Buchner et al., 2017). These positive trends of scaling up of climate finance means that the developing countries have more opportunity to get funding to support achievement of their renewable energy targets.

Efforts to increase and secure international funding to support renewable energy should be continued. Experts point out it is still much lower than the level needed to accomplish the goal to keep the average global temperature increase well below 2^0C despite the increase in climate finance. Furthermore, out of US$820 billion of climate finance in 2015 and 2016, the investment made by development finance institutions (DFIs) mostly supporting developing countries was only US $248 billion (Buchner et al., 2017). Considering at least US$11–108 billion is required annually only for 27 countries in the sample in this paper, DFIs need to scale up their climate finance. Another way to secure required investment is cutting down the cost through the development of renewable energy technologies. Buchner et al. (2017) analyzed the one of reasons why the investment decreased in 2016 compared to 2015 is falling technology cost. Decrease in renewable energy cost will minimize international resource requirements and help developing countries set more ambitious targets.

[4] REN21 (2017) provides a range of regional LCOE with minimum and maximum values. Minimum LCOE scenario refers the case that minimum LCOE value of a certain region is used to estimate required investment of countries located in the region, and maximum LCOE scenario refers the case that maximum LCOE value is applied.

Table 5
Levelized cost of electricity by region and technology.
Source: REN21 (2017). pp. 92–95

	LCOE (US$/kWh)					Capacity factor				
	Solar PV	Wind	Hydro	Bio	Geo- thermal	Solar PV	Wind	Hydro	Bio	Geo- thermal
Africa	0.07–0.26	0.06–0.16	0.03–0.21	0.03–0.16	0.04–0.13	0.20	0.37	0.43	0.62	0.84
Asia	0.04–0.26	0.04–0.22	0.02–0.21	0.04–0.08	0.04–0.11	0.16	0.25	0.47	0.67	0.85
Central America	0.10–0.20	0.16–0.35	0.07–0.16	0.04–0.06	0.09–0.10	0.19	0.35	0.53	0.60	0.58
Middle East	0.06–0.23	0.10–0.13	0.04–0.11	0.03–0.20	n/a	0.26	0.34	0.36	0.57	n/a
Oceania	0.08–0.14	0.07–0.11	0.09–0.13	0.04–0.13[a]	0.06–0.10	0.23	0.35	0.45	0.71[a]	0.80
South America	0.06–0.20	0.03–0.11	0.02–0.14	0.06–0.08	0.06–0.07	0.24	0.43	0.61	0.53	0.82
India	0.06–0.14	0.07–0.09	0.03–0.10	0.04–0.08	n/a	0.19	0.24	0.44	0.77	n/a

[a] estimated with average of the others.

Table 6
Estimated cost to meet the conditional renewable energy targets.

Country	Estimated cost (million USD)						Cost-to-GDP ratio (%)
	Solar PV	Wind	Hydro	Bio	Geothermal	Total	
Cambodia	2022.8–13,148.1	0.08–0.4	226.7–2380.5	13.9–27.7	–	242.7–2421.8	0.12–1.21
Colombia	122.2–407.5	544.8–1997.5	–	17.6–23.5	888.9–1037.1	1573.6–3465.5	0.06–0.12
Ethiopia	282.1–1047.7	1750.2–4667.3	11,271.0–78,897.1	418.7–2233.3	1677.7–5452.6	15,399.8–92,298.0	2.13–12.75
Fiji	112.6–197.0	–	163.9–236.8	143.7–466.9	–	420.2–900.7	0.91–1.94
Guyana	3.3–11.1	23.0–84.4	–	–	–	26.4–95.6	0.08–0.28
India	85,708.2–199,986	43,515.7–55,948.8	10,917.4–36,391.2	–	–	140,141–292,326	0.62–1.29
Indonesia	72.4–470.9	9.2–50.6	1000.5–10,505.0	6525.7–13,051.5	10,646.3–29,277.3	18,254.1–53,355.2	0.20–0.57
Jordan	6.8–26.2	3024.9–3932.3	–	–	–	3031.7–3958.5	0.78–1.02
Kiribati	1.5–2.6	–	–	–	–	1.5–2.6	0.09–0.16
Lao PDR	14.6–94.7	51.2–281.4	261.5 – 2746.0	148.4–296.7	–	475.6–3418.9	0.30–2.15
Mexico	1958.6–3917.2	13,355.3–30,526.3	13,389.0–30,603.5	–	–	28,702.9–65,047.0	0.27–0.62
Mongolia	128.1–256.2	358.1–818.6	1154.7–2639.3	–	–	1640.9–3714.1	1.47–3.33
Morocco	3383.1–12,968.4	6880.1–8944.1	922.7–2537.5	–	–	11,185.9–24,450.1	1.10–2.41
Mozambique	–	1711.4–4563.6	113.0–791.0	–	–	1824.4–5354.6	1.66–4.86
Myanmar	982.4–6385.7	214.9–1181.9	74.4–780.8	193.7–387.4	–	1465.3–8735.7	0.22–1.30
Nepal	637.7–4144.9	–	5048.7–53,011.9	284.1–568.1	–	5970.5–57,724.9	2.82–27.30
Papua New Guinea	6.4–11.2	13.8–21.7	1018.6–1471.3	29.6–96.1	233.6–389.3	1301.9–1989.5	0.77–1.18
Paraguay	–	–	3107.1–21,749.6	35.9–47.8	–	3142.9–21,797.4	1.15–7.94
Peru	63.1–210.2	–	–	–	–	63.1–210.2	0.003–0.01
Philippines	–	940.0–5170.0	2312.5–24,281.6	–	2530.9–6960.0	5783.4–36,411.5	0.19–1.19
Qatar	32.3–123.8	–	–	224.9–1499.5	–	257.2–1623.3	0.02–0.11
Rwanda	5.1–19.0	–	148.4–1038.5	–	501.8–1631.0	655.3–2688.5	0.78–3.21
Senegal	71.5–265.6	160.4–427.8	41.0–287.1	–	–	273.0–980.5	0.18–0.66
Thailand	791.6–5145.7	801.4–4407.7	223.1–2342.8	1828.4–3656.8	–	3644.5–15,552.9	0.09–0.38
Uganda	67.7–251.3	–	1274.5–8921.5	214.1–1141.8	–	1556.2–10.314.6	0.61–4.04
Vanuatu	24.6–43.0	4.2–6.7	–	–	18.5–30.8	47.3–80.5	0.61–1.04
Vietnam	3698.1–24,037.4	2814.2–15,478.1	4641.2–48,733.0	–	–	11,153.5–88,248.5	0.55–4.36
Total	98,176–260,036	76,173–138,509	57,310–330,346	10,079–23,497	16,498–44,778	258,235–797,166	0.41–1.28

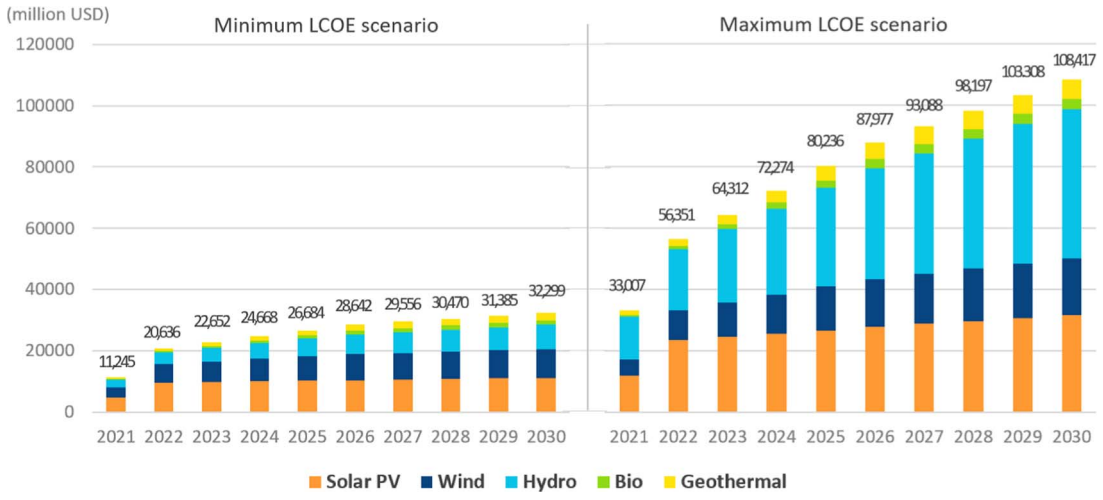

Fig. 3. Estimated annual investment needs.

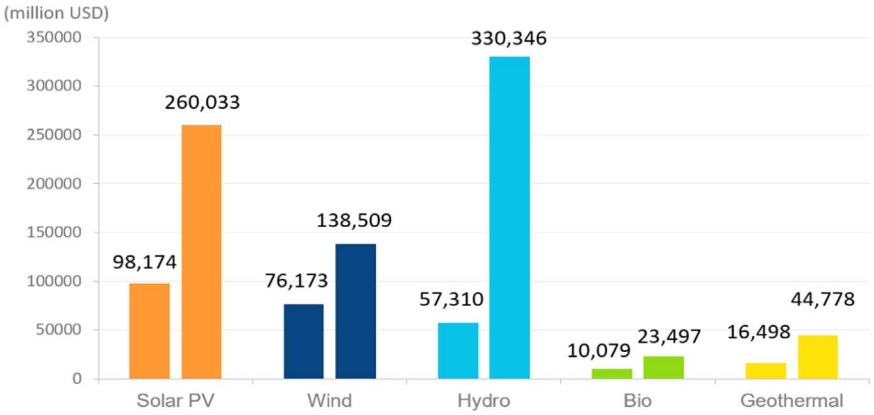

Fig. 4. Total estimated investment needs by technology.

With the increase in international finance, enabling environment in developing countries should be created as well. Despite funding, progress toward renewable energy objectives has been relatively slow due to multiple reasons, including lack of capacity and information, and inappropriate institutional frameworks and financing mechanisms (Betzold, 2016; Keeley, 2017; Timilsina and Shah, 2016). Capacity at various levels, including the local level, the energy planning and management levels, and the policy-making level, are important. Capacity and institutional frameworks are also necessary to attract international financing as it is more likely to ensure the success of projects. In fact, capacity of recipient countries and various political and institutional conditions including governance structures, transparency and dictatorship are increasingly considered in the distribution of development assistance, in order to prevent the unexpected failures. Thus, for developing countries to meet their targets, they also require the capability to implement, operate and maintain renewable energy projects as well as appropriate policies and institutional structures to support promotion of renewable energy.

International organizations, such as GGGI, can play a role in capacity building by both raising awareness of developing countries and supporting the elaboration of appropriate institutional frameworks. While the private sector can play a significant role in financial investment, building the capacity of governments and their citizenry is a realm in which the public sector has an advantage. In this sense, the international organizations could assist developing countries to create improved enabling environments to attract investments through supporting enhanced legal and regulatory frameworks for renewable energy investment and training officials and local stakeholders to raise awareness of renewable energy and improve the project management. Furthermore, by conducting investment potential and feasibility studies of various renewable energy projects it supports both government and the private sector investment decision-making.

7. Conclusion

This study examined contributions to GHG mitigation and renewable energy targets and estimated the investment required for achievement of the conditional renewable energy NDCs of GGGI member and partner countries by analyzing their NDCs and national energy plans. The 36 GGGI member and partner countries pledged GHG emission reductions of 5525.68 to 8910.54 $MtCO_{2eq}$, of that 5526 to 5538 $MtCO_{2eq}$ is unconditional and 3362 to 3373 $MtCO_{2eq}$ was conditional on climate finance. Examining renewable energy targets of the 27 GGGI member and partner countries that presented either conditional or combined targets, this study estimates that if fully achieved they would increase the cumulative renewable energy generation capacity up to approximately 356,184 MW, primarily in solar PV, hydropower, and onshore wind energy. Furthermore, at least US$258–797 billion is required to meet the combined and conditional renewable energy targets of the 27 countries by 2030. This investment can be made by national public budgets, international assistance and private sector sources, but international assistance should play a major role due to the premature market conditions and lack of budget of developing countries.

It is important to note this estimation should not be enough for meeting overall mitigation targets of GGGI member and partner countries. First, this estimation only covers the costs for meeting renewable energy targets. As stated earlier, GGGI member and partner countries planned various programs for mitigation in forestry, waste management, transportation and industry sector. Since those programs will also require funding, more investment should be secured to meet the conditional targets of GGGI member and partner countries. Second, renewable energy targets are likely to be increased. Because the current NDCs are insufficient to meet the objective of the Paris Agreement to keep the average global temperature increase well below 2 °C (UNEP, 2016; UNFCCC, 2015, 2016c), and the renewable energy targets of many developing countries is far lower than their total renewable energy potential, developing countries may increase their renewable energy targets, including their conditional mitigation targets. Rockström et al. (2017) have analyzed that the share of renewable energy must continue to double every 5.5 years until fossil fuel has exited the energy mix to achieve the goal of Paris Agreement. The system of Paris Agreement which requires countries to set more ambitious targets every five years will also urge developing countries to increase their renewable energy targets. If this is the case, more investments will be required.

This analysis provides vital basic information to determine how much climate financing should be scaled up. Considering the increasing trend of global climate financing, an estimation of the necessary funding to enable developing countries to undertake renewable energy-related GHG emission reductions is important. However, this result is still imperfect due to the quality of available data and uncertainties not considered, such as the projected cost of renewable energy, impact of technology development and policy change. Further studies that address these uncertainties and data gaps must be conducted. In order to address some of these issues systemically, it is recommended that the UNFCCC adopt standardized methodologies and formats before next NDC submission period expected 2019.

In addition to direct financial assistance, international organizations, including GGGI, should assist developing countries to achieve their targets by mobilizing public and private finance. They should also provide capacity building, policy recommendations, and technical assistance for the preparation of funding proposals for projects to achieve conditional renewable energy NDCs. Additionally, they should conduct investment potential and feasibility studies developing countries to help strengthen and concretize renewable energy investment for NDC implementation.

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